PRINCETON APPLIED RESEARCH®

INSTRUCTION MANUAL

CRYOGENIC TEMPERATURE CONTROLLER

Model 152

MP MASTER
MA30247

PRINCETON APPLIED RESEARCH CORPORATION

PRINCETON, NEW JERSEY

INSTRUCTION MANUAL

CRYOGENIC TEMPERATURE CONTROLLER

Model 152

THIS MANUAL APPLIES SPECIFICALLY TO MODEL 152 SERIAL NO. 132

Copyright 1969
Princeton Applied Research Corporation
Princeton, New Jersey

All rights reserved. Contents of this publication may not be reproduced in any form without written permission of the copyright owner.

M134; 1/69

Digitized by the Internet Archive
in 2025

https://archive.org/details/manualsplus_06094

TO THE ULTIMATE USER OF THIS UNIT

Princeton Applied Research Corporation is interested in seeing that you get maximum benefits from your purchase. We want to send you the latest in maintenance data, helpful suggestions for using the equipment, information on new accessories and the latest advances in the field. Please help us by filling in and returning one of the attached prepaid reply cards. Thank you.

(For subsequent or other users)

I will also be using a PAR

Model #_____, Serial #_____

Name_____, Title_____

Company_____

Address _____

_____

_____

Telephone_____

I plan to use the unit

for:_____

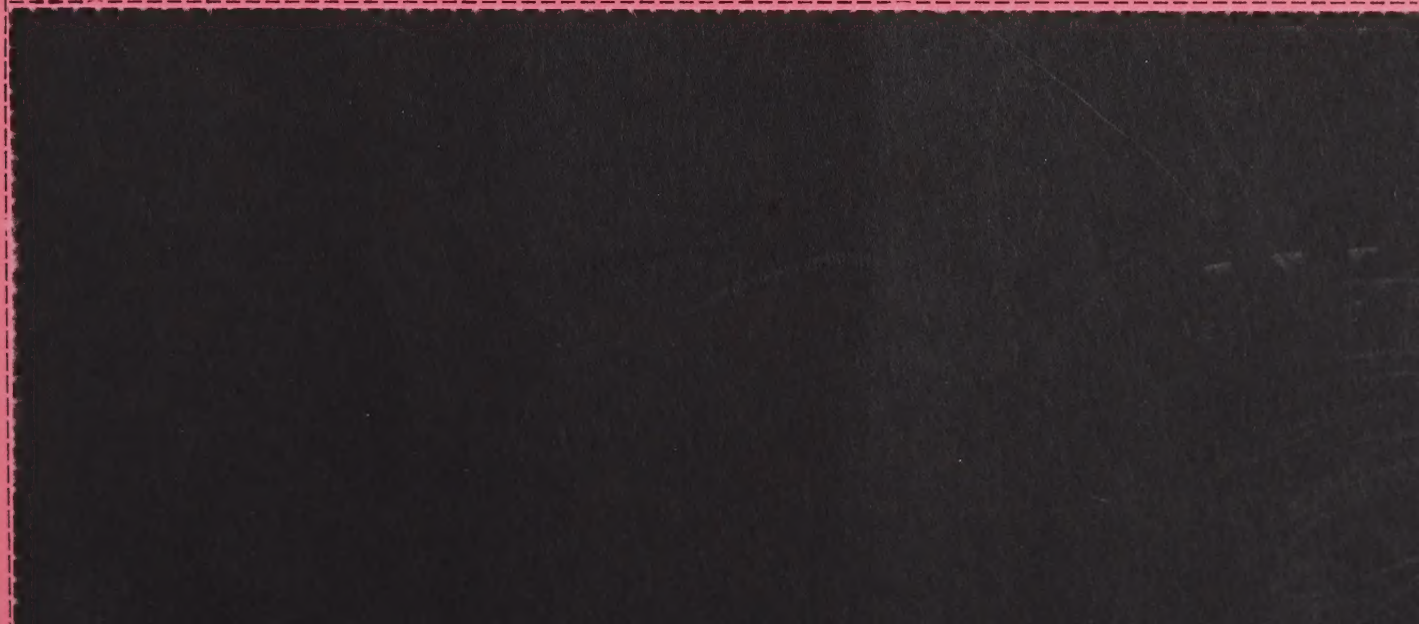
_____

_____

_____

_____

_____



First Class
Permit No. 285
Princeton, N. J.

BUSINESS REPLY CARD
No postage stamp necessary if mailed in the United States

Postage will be paid by

PRINCETON APPLIED RESEARCH CORP.

P. .O. BOX 565

PRINCETON, NEW JERSEY 08540

WHEN YOUR EQUIPMENT REQUIRES SERVICE

(YOUR WARRANTY IS IN EFFECT UNTIL 9-3-70)

A. Contact the factory (609-924-6835) or your local PAR representative to discuss the problem. In many cases it will be possible to expedite servicing by localizing the problem to a particular plug-in circuit board.

B. If it is necessary to send any equipment back to the factory, we need the following information:

1. Model # and serial #.
2. Your name (instrument user).
3. Your address.
4. Address to which instrument should be returned.
5. Your telephone number and extension.
6. Symptoms (in detail, including panel settings).
7. Your purchase order number for repair charges (does not apply to repairs in warranty).
8. Shipping instructions (if you wish to authorize shipment by any method other than normal surface transportation).
9. For your convenience, two service information cards are attached below. Please tape one of these cards or a page proving the above requested information directly to the instrument or equipment being returned.

C. U. S. CUSTOMERS — Ship the equipment being returned to:
Princeton Applied Research Corporation
Route 518 East of Route 206
Princeton, New Jersey

D. CUSTOMERS OUTSIDE OF U.S.A. — To avoid delay in customs clearance of equipment being returned, please contact the factory or the nearest PAR representative for complete shipping information. A list of representatives is included at the rear of this manual.

E. Address correspondence to:
Princeton Applied Research Corp.
P. O. Box 565
Princeton, New Jersey 08540

MY PAR EQUIPMENT REQUIRES SERVICE

It is a Model # 152, Serial # 132

The malfunction is _____

Name _____, Title _____

Company _____

Address _____

Telephone _____, Ext. _____

Please return instrument to me at (address)

Via (shipping method) _____

Signed _____

Purchase Order # _____

MY PAR EQUIPMENT REQUIRES SERVICE

It is a Model # _____, Serial # _____

The malfunction is _____

Name _____, Title _____

Company _____

Address _____

Telephone _____, Ext. _____

Please return instrument to me at (address)

Via (shipping method) _____

Signed _____

Purchase Order # _____

First Class
Permit No. 285
Princeton, N. J.

BUSINESS REPLY CARD
No postage stamp necessary if mailed in the United States

Postage will be paid by

PRINCETON APPLIED RESEARCH CORP.

P. .O. BOX 565

PRINCETON, NEW JERSEY 08540

First Class
Permit No. 285
Princeton, N. J.

BUSINESS REPLY CARD
No postage stamp necessary if mailed in the United States

Postage will be paid by

PRINCETON APPLIED RESEARCH CORP.

P. .O. BOX 565

PRINCETON, NEW JERSEY 08540

ADDENDUM

PART I

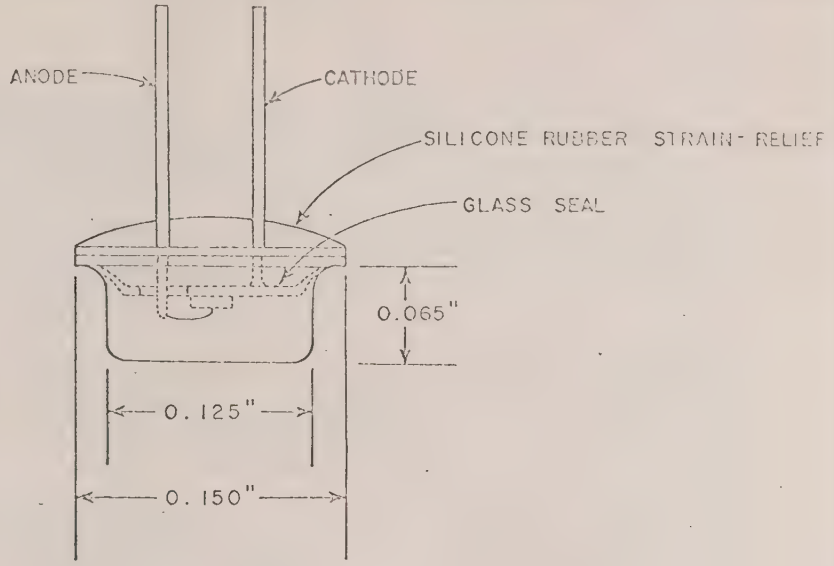
The voltage drop across the gallium arsenide sensor at 4.2 K may be as small as 1.32 volts in some of the early units and as large as 1.65 volts in some of the more recent units, as a result of sensor improvements to increase sensitivity at the lowest temperatures. The set-point voltage interval covered in the low range position is only 0.1 volt wide - insufficient to cover the observed spread in sensor outputs.

A switch has been included in the more recent units to offset the set-point range in 10 steps of 50 millivolts each. This permits the operator to shift the range covered by the ten-turn set-point dial to match the sensor being used. With the switch in position 1 the set-point dial spans a sensor range of from 0.3 volt to 1.3 volts with a high range setting, and spans a sensor range of from 1.2 volts to 1.3 volts with a low range setting. In position 2 the corresponding ranges are 0.35 to 1.35 volts and 1.25 to 1.35 volts, and so on up to position 10 with corresponding ranges of 0.8 to 1.8 V and 1.7 to 1.8 V.

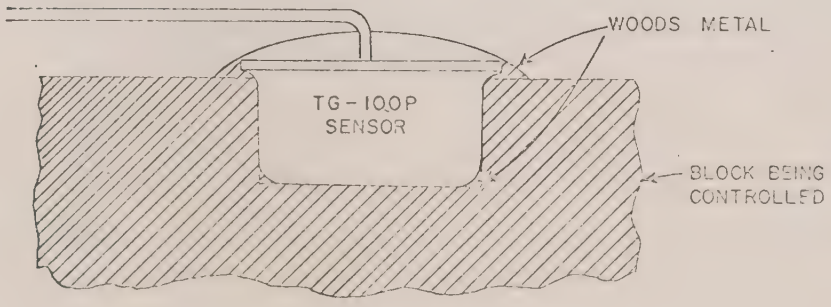
When following the directions given in the Initial Checks section and in the Alignment Procedure, the offset switch should be in position 4 so that the procedures for the modified and unmodified units are alike.

The TG-100-P diode used in [illegible] has a hat-shaped case with a crown diameter of 0.125", a crown height of 0.070", and a brim diameter of approximately 0.150". A satisfactory pocket in which to mount the diode can be prepared by making a 1/16" deep cut with a 1/8" diameter end mill. The pocket should be tinned with Woods alloy. While the alloy is molten, the sensing element is pressed into the pocket and twisted to achieve a scrubbing action. The element is then withdrawn and examined to determine the degree of surface wetting. If necessary, a solution of dilute zinc chloride or liquid flux solution is used to achieve uniform wetting of the pocket and element. The work-piece and element are then separated and thoroughly washed with water to remove any flux residue. The work-piece is again heated to 80°C-100°C. Then the sensor is inserted and held in place while the work-piece is cooled.

This procedure should result in a rigid mechanical contact with excellent thermal characteristics. Diagrams of the temperature sensing diode and a typical installation are on the following page.



TG-100-P GaAs TEMPERATURE
SENSOR OUTLINE



TYPICAL INSTALLATION
OF GaAs TEMPERATURE SENSOR

TABLE OF CONTENTS

Section		Page
I	CHARACTERISTICS	I-1
	1.1 INTRODUCTION	I-1
	1.2 SPECIFICATIONS	I-2
II	INITIAL CHECKS	II-1
	2.1 INTRODUCTION	II-1
	2.2 EQUIPMENT NEEDED	II-1
	2.3 PROCEDURE	II-1
III	OPERATING INSTRUCTIONS	III-1
	3.1 INTRODUCTION	III-1
	3.2 PRELIMINARY CONSIDERATIONS	III-1
	3.3 FRONT-PANEL ADJUSTMENTS	III-3
IV	CIRCUIT DESCRIPTION	IV-1
	4.1 INTRODUCTION	IV-1
	4.2 DIFFERENTIAL AMPLIFIER	IV-1
	4.3 COMPUTER CIRCUITRY	IV-1
	4.4 BOUND CIRCUITRY	IV-2
	4.5 DRIVER AMPLIFIER	IV-2
	4.6 ±15 V REGULATED POWER SUPPLY	IV-3
V	ALIGNMENT PROCEDURE	V-1
	5.1 INTRODUCTION	V-1
	5.2 EQUIPMENT NEEDED	V-1
	5.3 PROCEDURE	V-1
VI	TROUBLESHOOTING	VI-1
	6.1 INTRODUCTION	VI-1
	6.2 PROCEDURE	VI-1
	6.3 PRINTED CIRCUIT SOLDERING	VI-1
VII	WARRANTY	VII-1
VIII	SCHEMATICS (table of)	VIII-1
LIST OF SALES OFFICES		LAST PAGE

FIGURES

Number	Title	Page
I-1	PHOTOGRAPH	I-2
III-1	FUNCTIONAL BLOCK DIAGRAM	III-2
III-2	TEMPERATURE CONTROL CHARACTERISTICS	III-4
VI-1	SOLDER REMOVAL BY WICKING	VI-3

SECTION I
CHARACTERISTICS

1.1 INTRODUCTION

The PAR™* Model 152 Cryogenic Temperature Controller is capable of providing precise continuous temperature control in the range of 4.2 K to 300 K. Although designed specifically as an accessory to the liquid helium dewars used with the PAR™ Vibrating Sample Magnetometer Systems, the Model 152 may be useful in other cryogenic systems which exhibit minimum lag between thermal input and response.

When used in conjunction with the dewar of the PAR™ magnetometer systems, temperature control is possible from 4.2 K to 300 K and, by evacuating the sample chamber, this lower limit can be extended to approach 1.5 K. The Model 152 controls the temperature of the sample by sensing the temperature of a vapor stream emerging from a small heat exchanger in the Magnetometer System and governing the current supplied to a heating coil in the exchanger. This vapor stream determines the temperature of the sensor and the sample zone located above the sensor. Locating the sensor just above the heat exchanger minimizes control time lag. Researchers with precision, low-temperature thermometers can calibrate their sensor by inserting the thermometer in place of the sample.

An uncalibrated gallium arsenide diode which combines sensitivity, magnetic field independence, wide range, and repeatability is utilized as the sensor. Sensor dissipation is limited to 1.5×10^{-5} watts maximum. A computing amplifier is used to achieve prompt response with stability over the entire operating range. The day-to-day repeatability is better than ±0.1 K and the stability is better than ±0.01 K. In tests in which the Model 152 was used with the thermal system incorporated into a PAR™ Model 153 Cryostat, no overshoot was evidenced, even though the thermal time-constant of the system changes by as much as a factor of 6,000 due to changes in specific heat and thermal conductivity as the temperature is varied over the range of 4.2 K to 300 K.

Front-panel controls include a ten-turn dial which is used to set the temperature control point, a manual heater control potentiometer, an automatic-manual selector switch, four screwdriver controls which allow the servo-loop parameters to be adjusted, and a range switch which allows the low-temperature control range (4.2 K to 60 K) to be expanded. A null meter which indicates deviation from the selected temperature setting, a heater current meter, and a lamp which indicates a limited mode of operation are also included on the front panel.

*PAR is a trademark of Princeton Applied Research Corporation.

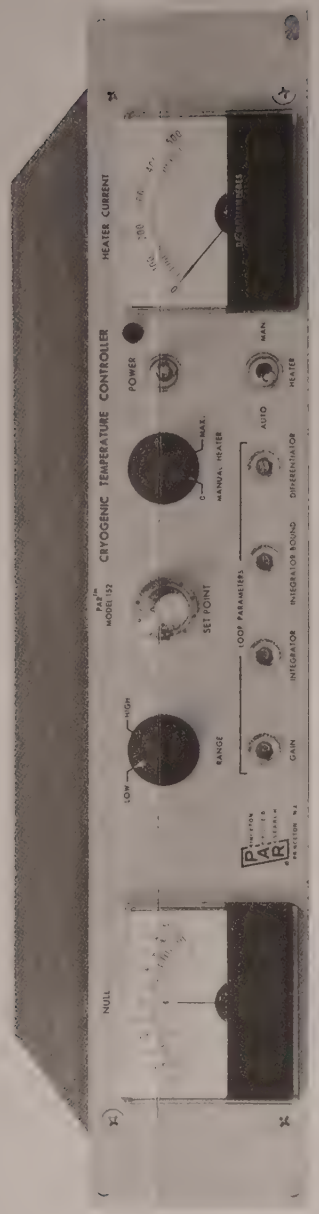


Figure I-1. MODEL 152 CRYOGENIC TEMPERATURE CONTROLLER

1.2 SPECIFICATIONS

(1) SENSOR

Uncalibrated gallium arsenide diode.

(2) SENSOR CURRENT

10 μA for a maximum dissipation of 1.5×10^{-5} watts.

(3) HEATER OUTPUT

0 to 500 mA dc (10 V max.).

(4) HEATER CONTROL

Manual or automatic. In manual control mode, heater current is set with front-panel control and monitored by panel meter. In automatic control mode, current is automatically regulated to the value required to achieve and maintain the temperature corresponding to the dial setting.

(5) SET-POINT SELECTION

Set-point is determined by setting a single ten-turn dial with a resolution better than 1 K over the entire range. Associated switch allows choice of two ranges, high, typically 4.2 K to 300 K, and low, typically 4.2 K to about 60 K. By evacuating the sample chamber the lower limit is extended to approximately 1.5 K.

(6) RESPONSE TIME

In the vicinity of 20 K, 10 K/s with less than 0.1 K null deviation during the setting operation. There is no overshoot.

(7) STABILITY

±0.01 K per hour.

(8) SAMPLE TEMPERATURE, CONTROL OFFSET

When operating the Model 152 in conjunction with the Model 150 Vibrating Sample Magnetometer, if the refrigerant flow is adjusted such that a heater current of 250 mA is required to maintain a heat exchanger outlet temperature of 35 K, the sample zone temperature will stabilize to within ±0.25 K for any set-point dial setting. (Temperature offset between sensor and sample zone is less than 1/2 K.)

(9) INSTALLATION

Mounts in standard 19 inch relay rack (panel height 3 1/2 inches). There are four connections to the cryostat, two for the heater and two for the sensor diode. Installation for operation with the Model

150 Vibrating Sample Magnetometer is particularly easy because the Model 150 dewar is supplied with the sensor diode installed. Separate sensor installation is required to use the Model 152 with any other cryostat. Contact the factory for information regarding the compatibility of the Model 152 with dewars other than that supplied with the Model 150 Magnetometer or that available as an option for use with the Model FM-1 Magnetometer.

(10) POWER REQUIREMENTS

105-125 V rms or 210-250 V rms, 50-60 Hz, 50 volt-amperes.

(11) WEIGHT

Eleven pounds.

SECTION II
INITIAL CHECKS

2.1 INTRODUCTION

The following procedure is provided to facilitate initial performance checking of the Model 152. In general, the procedure should be performed after inspecting the instrument for shipping damage (any noted to be reported to the carrier and to Princeton Applied Research Corporation), but before using it experimentally. Should any difficulty be encountered in carrying out these checks, contact the factory or one of PAR's authorized representatives, a list of whom appears at the end of the manual. These checks are described so that the checker need not have any prior knowledge of the instrument.

2.2 EQUIPMENT NEEDED

(1) 147 kilohm ±1% resistor.

(2) 20 ohm, 5 watt resistor.

2.3 PROCEDURE (To be followed sequentially)

Place the instrument on a bench or in a relay rack. Open the top cover, and notice the slide switch next to the transformer. Move the switch so that the number corresponding to the desired line power voltage, 115 V ac or 230 V ac, shows in the switch window. Replace the cover and connect the line power. Connect the 147 kilohm resistor to the rear-panel DIODE terminals. Then connect the 20 ohm resistor to the rear-panel HEATER terminals. Turn the Power switch to On.

Some of the Model 152 units have the Loop Parameter controls preset for use with a particular Cryogenic system, and these controls should not be disturbed for an operating check. Other units do not have these controls set up, so the controls will require adjustment in order to perform a satisfactory check. Two sets of procedures are given, therefore, one for the Loop Parameter controls preset and one for them not preset. If the checker is not sure if the controls are preset or not, it is best to follow the PRESET procedure first, and then, if necessary, go to the NOT PRESET procedure. Units which are shipped from the factory are generally preset prior to shipment.

(1) LOOP PARAMETERS CONTROLS PRESET

(a) Set the Range switch to the Low position.

(b) Set the Heater switch to the Automatic position.

(c) Adjust the Set Point potentiometer so that the Null meter reads zero.

(d) With the Null meter at zero, note that the Heater Current meter is on scale and maintains a nearly constant reading.

(e) Quickly turn the Set Point potentiometer clockwise so that the Null meter moves slightly to the left. Note that the Heater Current meter moves up scale and then "bounces" back, and then returns moves slowly up scale again.

(f) Adjust the Set Point control so that the Null meter reads about 8/10 of full-scale (either direction). The Bound light should come on with the Null meter reading more than 8/10 of full-scale, and the light should be off with the meter reading less than 8/10 (approximately). Note that with the Bound light on, the Heater Current meter maintains a nearly constant reading.

(2) LOOP PARAMETERS CONTROLS NOT PRESET

(a) Set the Range switch to the Low position.

(b) Set the Heater switch to the Automatic position.

(c) Turn all Loop Parameter controls fully counterclockwise.

(d) Turn the Gain control about 1/4 turn from fully counterclockwise in the clockwise direction.

(e) Adjust the Set Point control so that the Null meter reads about 8/10 of full scale (either direction).

(f) Adjust the Integrator Bound control so that the Bound lamp is at threshold with the Null meter at 8/10 of full-scale.

(g) Turn the Integrator control about 1/2 turn in the clockwise direction.

(h) Adjust the Set Point control so that the Null meter is at zero. Note that the Heater Current meter maintains a nearly constant reading.

(i) Turn the Set Point control clockwise so that the Null meter moves to the left of zero but not so far as to make the Bound lamp come on. Note that the Heater Current meter moves slowly up-scale (rate of up-scale movement depending upon the Integrator control setting.

(j) Turn the Set Point control clockwise so that the Bound lamp comes on. Note that the Heater Current meter maintains a nearly constant reading, and does not move up-scale.

(k) Adjust the Set Point control so that the Null meter reads zero.

(l) Turn the Differentiator control full clockwise, or nearly full clockwise.

(m) Quickly turn the Set Point control clockwise so that the Null

Meter moves to the left (but not so far as to make the Bound lamp come on). Note that the Heater Current meter moves up-scale and then [redacted] returns, and then moves slowly up-scale again.

This completes the Initial Checks. If the instrument performed as described, one can be reasonably sure that it is operating properly.

SECTION III
OPERATING INSTRUCTIONS

3.1 INTRODUCTION

To enable maximum performance to be obtained from the Model 152 Cryogenic Temperature Controller, detailed operating instructions are provided. These instructions are divided into two parts; the first dealing with preliminary considerations, such as installation and primary power requirements, and the second dealing with the front-panel controls and loop parameter adjustments.

3.2 PRELIMINARY CONSIDERATIONS

INSTALLATION

The Model 152 is designed to be bench mounted or rack mounted in a standard 19 inch relay rack (panel height 3-1/2 inches).

POWER REQUIREMENTS

Approximately 50 volt-amperes at either 105-125 V or 210-250 V, 50-60 Hz, are required. Changeover from one voltage to the other is accomplished by operating an internal slide switch. The internal line-voltage slide switch is mounted next to the power transformer, and is made accessible by removing the top cover. For operation from 105-125 V, "115" should show in the switch window, and for operation from 210-250 V, "230" should show.

FUSING

There are four fuses in all; two mounted on the rear panel, and two mounted internally. The two internal fuses, mounted next to the power transformer, are power supply fuses and are each 3AG 0.3A 250V fuses. One of the rear-panel fuses is the line power fuse, and the other is the heater amplifier fuse. The line power fuse is the lower of the two rear-panel fuses and is a 3AG 1/4A 250V Slow-Blow fuse. The heater amplifier fuse is the upper of the two rear-panel fuses, and is a 3AG 1/2A 250V Slow-Blow fuse. The values of these fuses should be verified prior to initial operation.

CRYOGENIC SYSTEM INTERCONNECTIONS

The Model 152 Cryogenic Temperature Controller need only be connected to the sensing element and the heater. Temperature sensing diodes and heaters are provided already installed in the liquid helium dewars used with the PAR Vibrating Sample Magnetometer systems. A shielded cable with two twisted pairs of copper wire should be sufficient to make the connections.

The smaller pair of terminals at the rear of the instrument are the heater connections. 0 to 500 mA of dc control current are available at these terminals. Supply voltage is +30 volts, but a 20 ohm limiting resistor is used to limit the current on shorting to a value not damaging to the pass transistor. A 1/2 ampere Slow-Blow fuse also protects this output circuit (see above).

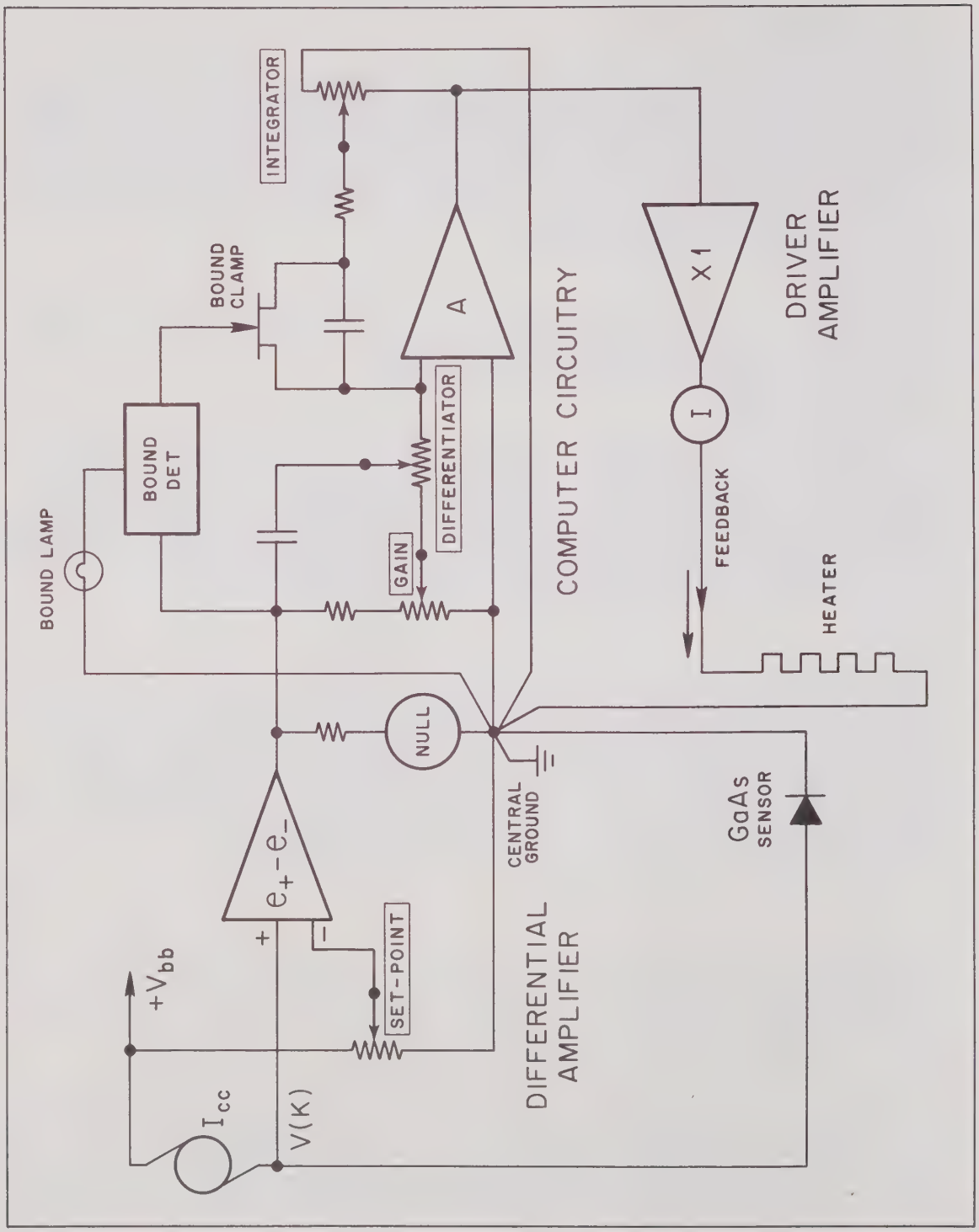


Figure III-1. MODEL 152 FUNCTIONAL BLOCK DIAGRAM

The power amplifier voltage gain is determined by an internal adjustment, which is made for the individual heater used (nominally 20 ohms in PAR systems) so that maximum heater current is 500 mA. See Section V, the Alignment Procedure, for instructions on how to make this adjustment. Note that units which are shipped for use with a specific Cryogenic system are preadjusted at the factory. If more power is required than is available from the Model 152, a power amplifier stage may be added to achieve the required level. Since energy removal by boiling helium can cost $8,000.00 per kilowatt hour, we suggest equipment designs which are satisfied with the 10 watt nominal power capacity of the Model 152.

Two large terminals are provided at the rear of the instrument for connecting to the temperature sensing diode. These terminals are made of copper so that when using bare copper, connecting-wire thermal emf's are avoided. The red terminal must connect to the anode, and the black terminal must connect to the cathode. The diode cathode is internally connected to the element case, and may be identified with an ohmmeter. WARNING: The diode may be damaged by energizing with the wrong polarity. Do not apply more than 3 volts when identifying leads. Use the ohmmeter on the low ohms range only so that no more than 1½ volts is applied to the diode. Do not turn on the Controller until the correct polarity has been verified.

In Cryogenic units other than those supplied by Princeton Applied Research, the user may find it necessary to supply his own diode. Recommended diodes are: Lake Shore Cryotronics #TG-100P, Phylatron #CD-500APT, or equivalent. Typical specifications are located at the end of Section VIII.

INITIAL TURN-ON CHECK

When the heater and sensing diodes have been connected, set the Manual Heater current control to full counterclockwise, and set the Heater toggle switch to Manual. Set the Range switch on High. Turn on power. Adjust the Set Point control until the Null meter is on scale. Check the heater briefly by increasing the Manual Heater control to obtain a reading on the Heater Current meter, and check for a response on the Null meter due to heater power. Return the Manual Heater control to zero.

3.3 FRONT-PANEL ADJUSTMENTS

Before discussing the particulars of the front-panel settings, details of the feedback loop and its controlling action are considered.

FUNCTIONAL BLOCK DIAGRAM DISCUSSION

Referring to the Functional Block Diagram on page III-2, note that the sensor is driven by a constant-current source so that the sensor output is a voltage function of temperature. This voltage is compared with a reference (set-point) voltage by a Differential Amplifier, and the error voltage is in turn applied to the Computer circuitry. The output of the Computer circuitry goes to the Heater via the Driver Amplifier to complete the feedback loop. Individual returns are brought to a central ground-point to minimize the effects of ground-loop currents.

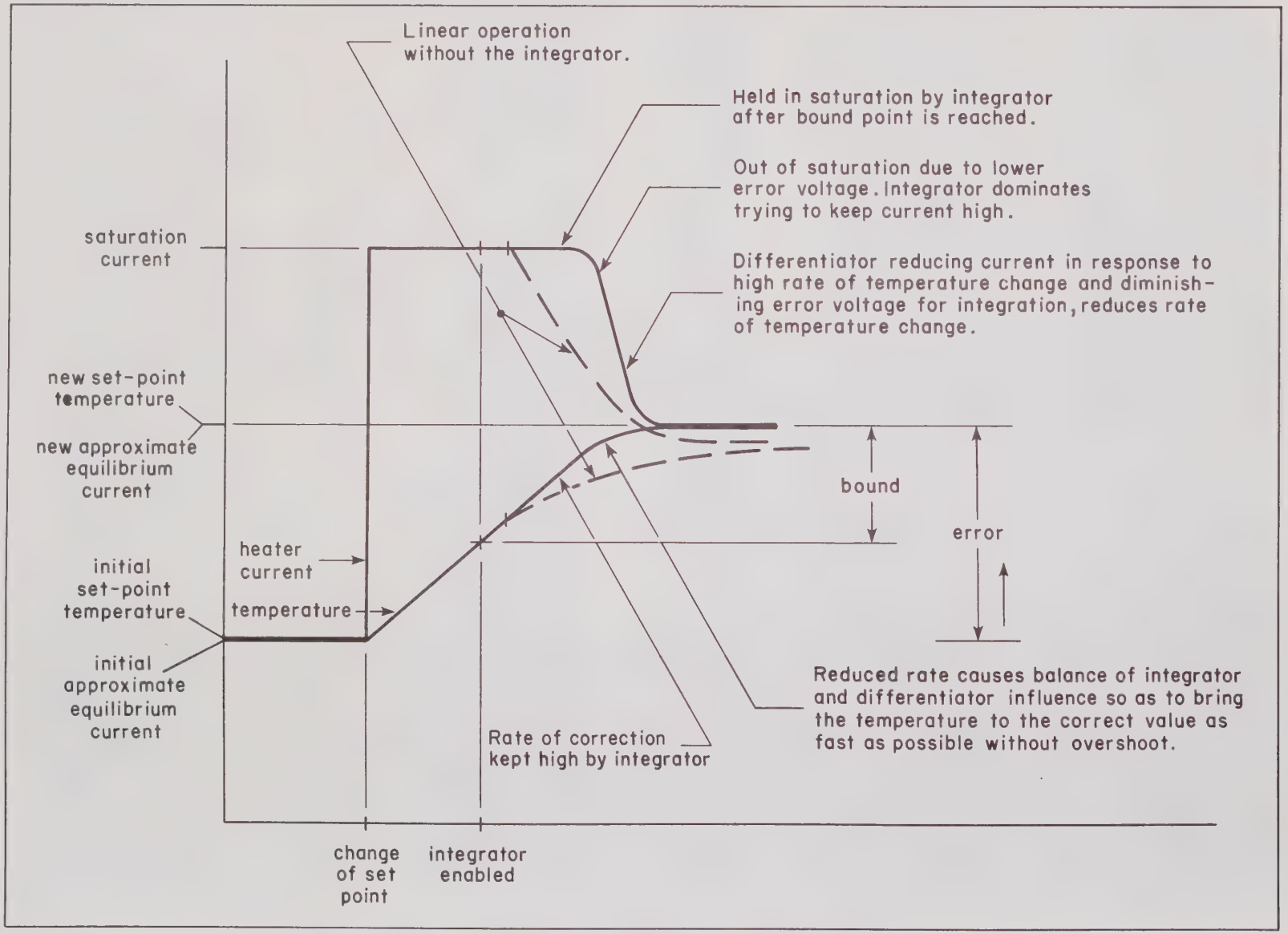


Figure III-2. TEMPERATURE CONTROL CHARACTERISTICS

The Computer circuitry provides three-term, proportional-deriavative-integral control by combining conventional augmented differentiator and integrator circuit functions. During periods of large error, the integration function is disabled by the "Bound Clamp" FET to prevent the integrator from using up its dynamic range. To help with the discussion of the way this circuitry controls the temperature, the curves of Figure III-2 on page III-4 will be used. These curves are idealized in the sense that system non-linearities will alter them considerably. For each system temperature point, there is a corresponding approximate "equilibrium" heater current. If the temperature is greater than a given desired point, then the heater current should be reduced to allow the coolant to reduce the temperature. Conversely, if the temperature is lower than desired, the heater current should be increased. However, it is most desirable to have the temperature approach the set temperature as fast as possible, and then level off without overshooting or leveling off too slowly, and no constant error or oscillation should exist. This is done by driving the heater with much more current than equilibrium current or much less current than equilibrium current, depending upon the direction of error, and accordingly reducing or increasing the current as the temperature approaches the desired temperature. At this point it would be useful to assume a system temperature which is below the set-point temperature, with the understanding that the functioning of the circuitry for the other direction of error is similar. With a large temperature error, the output of the GaAs diode is very much different from the set-point reference voltage, so that a large error voltage appears at the output of the differential amplifier. If the error voltage is large enough, the Bound detector circuit is activated which short-circuits the integrator capacitor, and the large error voltage causes the heater driver amplifier to be saturated so that the temperature most rapidly increases. As the error voltage becomes smaller, the point is reached where the Bound circuit unclamps the integrator and the integrator begins to integrate the diminishing error voltage. Had the integrator remained disabled, the controlling circuitry would have continued to linearly amplify the diminishing error voltage, so that eventually the driver amplifier would have come out of saturation to allow the rate of temperature increase to gradually reduce (but never allow the temperature to reach the set-point) However, the integrator, as a result of integrating the diminishing error voltage, keeps the driver amplifier in saturation so that the temperature continues to rapidly increase. With large error voltages the integration function of the circuitry dominates, but as the error becomes smaller the integrator has less voltage to "work with" in trying to keep the current high. But the differentiator, on seeing the large rate of change of error voltage, works "against" the integrator in determining the control circuitry output so that as the error becomes smaller the heater current is reduced. As long as an error exists, the integrator tends to increase the heater current so as to reduce the error as fast as possible; the larger the error and the longer the error exists, the larger the correction. But as a result of the rapid change in temperature and diminishing error, the differentiator component gains influence and tends to reduce the heater current so that the rate of change of temperature decreases. Consequently, the integrator, in trying to increase the temperature to reduce the error voltage, and the differentiator, in trying to reduce the rate of change of temperature, interact so that the temperature rapidly approaches the set-point and then levels off sharply to the set-point. In other words, the system tends to

quickly stabilize so that both the error voltage and the slope of the error voltage are zero, and this can occur only at the set-point. If the parameter controls are set so that integration overbalances differentiation, the system will go through a damped oscillation about the set-point. If the differentiation overbalances the integration, then the system will take too long to get to the set-point temperature. The sensitivity of the integration and differentiation functions depend upon the respective control settings, but the overall system sensitivity is determined by the proportional gain control setting. With this control set too low the full dynamic control range will not be in use. The parameter controls should be set-up so that a temperature error is corrected as quickly as possible without overshoot.

LOOP PARAMETER ADJUSTMENTS (For units not preadjusted at the factory)

(1) After connecting the Controller as in Paragraph 3.2, perform the Initial Turn-On Check as described in that paragraph (page III-3).

(2) Start with the Gain, Integrator, and Differentiator controls fully counterclockwise, and the Bound control clockwise.

(3) Move the Set-Point control clockwise until the Null meter is off-scale to the left, then turn the Set-Point control 1/2 turn more (clockwise).

(4) Switch from Manual to Automatic, then quickly adjust the Gain to just achieve 500 mA of Heater Current. WARNING: Prolonged operation at full current may overheat the heat exchanger to destruction.

(5) Switch back to Manual and adjust the Set-Point to obtain an on-scale Null meter reading.

(6) Return to Automatic control.

(7) Increase (clockwise) the Integrator control until the off-set begins to diminish to not more than 20% of full scale on the Null meter.

(8) Rotate the Differentiator control clockwise until the Null meter fluctuations are 180° out-of-phase, and oscillations tend to die out.

(9) Make fine adjustments of the Gain, Integrator, and Differentiator controls to achieve the most rapid response without oscillation.

(10) Switch to Manual control and adjust the Bound control until the Bound indicator lights at approximately 3/4 scale (either direction) on the Null meter.

The time-constant of the thermal system is approximately proportional to the thermal capacity divided by the thermal conductivity. The specific heat of materials decreases to zero at zero K, and the conductivity of pure metals, such as copper, increases to a maximum at about 10 K before dropping off sharply below 2 K. The result is to shorten the time-constant of the system drastically at temperatures between about 4 K and 60 K. The time-constant of a typical system decreases by a factor of approximately 6×10^3 as it is

cooled from room temperature to 4.2 K. To achieve stable temperature control over the entire operating range, the Loop Parameters should be set at the low-temperature fast-time constant point. As the set-point is increased, the control response time would tend to be slower than is possible. But this is better than setting-up at high temperatures and over-controlling (oscillating) at low temperatures. If optimum control is required at a given set-point, the Loop Parameters should be adjusted at that set-point.

Considerable latitude in adjustment range has been incorporated into the Loop-Parameter controls to provide for use of the Controller with less than ideal thermal systems. If the time constant of the thermal system is long, the effects of random disturbances of short duration cannot be eliminated by the Controller, and the time to reach equilibrium after a change in load or set-point will be increased. The importance of good thermal system design with minimum phase lag cannot be overemphasized.

It is recommended that the application of the Model 152 Controller be discussed with Princeton Applied Research before it is ordered for systems of other than PAR manufacture.

SECTION IV
CIRCUIT DESCRIPTION

4.1 INTRODUCTION

Temperature control is achieved by the Model 152 as described in Section III. This section, therefore, begins immediately with the specific circuit descriptions with the understanding that the Functional Block Diagram discussion of paragraph 3.3 has been referred to by the reader. In addition to the Comparator Amplifier, Computer Circuitry, Bound Circuitry, and Driver Amplifier, a Power Supply and associated ±15 V Regulators are included.

4.2 DIFFERENTIAL AMPLIFIER

Referring to the Differential Amplifier schematic on page VIII-2, note that CR1 is the temperature sensing diode mounted on the cryogenic system. Q200 serves as a current source to supply a constant 10 μA to CR1 so that the voltage at the CR1 anode is a sensitive and accurate function of temperature as specified by the diode manufacturer. S4, the Range switch, selects one of the voltage divider configurations to determine the range of voltages to be selected by the Set-Point potentiometer for use as a reference. With the Range switch in the Low position, the switch-arm is to the right as shown on the schematic, so that the voltage selected by the Set-Point potentiometer R7 ranges from 1.4 V to 1.5 V. With the switch arm to the left, the voltage selected by the Set-Point potentiometer ranges from 0.5 V to 1.5 V. The voltage from the temperature sensing diode and the reference voltage are applied to the inputs of the differential amplifier comprising Q201, Q202, and A200. Q201 is used as the front-end of the amplifier to allow offset voltages to be compensated, and, in addition, both sides of Q201 are matched and mounted together in a constant-temperature oven to provide a temperature-stable, zero-drift, zero-offset, amplifier-input stage. The amplifier output is a voltage of approximately 1000 times the difference of the reference voltage and the sensor voltage. The Null meter across this output is deflected to full-scale with an output of 1 V (difference between sensor and reference voltages of 1 mV). Two outputs from the Amplifier are utilized: a direct output, taken from pin 43, goes to the Bound circuitry, and the direct output and the attenuated output from the wiper of the Gain potentiometer go to the Computer circuitry.

4.3 COMPUTER CIRCUITRY

The Computing circuitry is an augmented proportional-differentiator-integrator analog computer built around an operational amplifier comprising Q114, Q115, and A100 (see schematic on page VIII-3). Q114 and Q115 are a matched FET pair used for the front end so that loading, drift, and offset are minimized, and what offset does exist may be compensated by R150. The direct output from the Differential Amplifier, applied to pin 23, first goes to the differentiator RC network, R137 and C113, and then goes to the front-Panel Differentiator Adjust potentiometer R6. C113 differentiates the input while R137 and R6 determine the gain of differentiation. The attenuated Differential Amplifier output, applied to R6 via S1, in bypassing the differentiator

circuitry, adds a linear gain component to the computation. CR110-CR113 constitute a back-biased, temperature-compensated, diode network which provides over-voltage protection for the FET input transistor Q114. The voltage at the gate of Q114 is limited to about ±1 V. C115 is the integrator capacitor. R156 is the feedback proportional-gain resistor. R1 divides down the feedback voltage to determine the gain of integration. Note the interaction of the various control functions. Q118 short-circuits the integration capacitor when the bound circuit is activated, and will be discussed in conjunction with the Bound circuit discussion. The output of the Computer circuitry, taken from pin 32, goes to the Driver Amplifier via the front-panel Manual-Automatic switch.

4.4 BOUND CIRCUIT

The direct output of the Differential Amplifier activates the Bound circuit when the voltage becomes larger than a predetermined value. The Bound circuit in turn closes the FET switch Q118 (schematic on page VIII-3) and lights the Limit indicator lamp. The closing of FET Q118 disables the integrator for large error voltages to prevent the integrator from using up its dynamic range before the error is corrected. With zero volts input to pin 28, the equal outputs of current transistors Q112 and Q113 go entirely to the emitters of the respective transistor to which each is connected (Q110 and Q111 respectively). A positive voltage at pin 28 is divided by the resistive voltage divider R131 and R4. The voltage across R4 allows current to be drawn away from the collector of Q113; the amount depending upon the input voltage and the setting of R4. Therefore, an increased current and corresponding decreased voltage appear at the collector of Q110, and a decreased current and corresponding increase in voltage appear at the collector of Q111. A negative input voltage at pin 28 causes the complementary action to occur. CR116 and CR117 are biased so that a decrease in either collector voltage appears at the base of Q116, but an increased voltage is blocked. The circuit just described therefore acts somewhat like a full-wave rectifier with gain. Q116 and Q117 are a differential amplifier pair used as a switch. With no signal input, Q116 is biased off and Q117 is on. -15 V appears at the collector of Q116 during Q116 cut-off, serving to keep FET switch Q118 open and also reverse biasing Q119. As the voltage at the base of Q116 decreases, Q116 becomes forward biased and soon becomes saturated due to the high-gain characteristics of the transistors. The collector voltage of Q116 tends to change from the cut-off value of -15 V to the saturation value of about +15 V, but is clamped to 0 V by CR118. Zero volts therefore appears at the gate of Q118 when the output of the Differential Amplifier exceeds an absolute value determined by the setting of the Bound potentiometer, closing the switch to short-circuit C115. R155 limits the peak current through Q118. The zero volt level also causes Q119 to saturate and turn on the lamp.

4.5 DRIVER AMPLIFIER

Since the maximum heater power required is 20 watts, a Driver Amplifier is employed. Referring to the schematic on page VIII-3, note that this amplifier is an operational amplifier comprising Q120, Q121, Q122, and Q3. Q3 is the emitter-follower output stage which is current-limited by R173. R170 and R171 are the feedback divider which determines the voltage gain. CR120 is a

limiter diode which limits the maximum input voltage at about 6 V, thereby determining the saturation point described in the Block Diagram discussion. With a given heater load, R171 is adjusted so that the load current is 500 mA at saturation. A voltage from the front-panel Manual Heater potentiometer is used as a Driver Amplifier input when the Heater switch is in the Manual position.

4.6 ±15 V REGULATED POWER SUPPLY

The ac line voltage is stepped-down by a transformer and full-wave rectified by the bridge rectifier CR2-CR5 (schematic on page VIII-3). ±35 V outputs from the rectifier circuit go to the ±15 V Regulators, and +35 V goes to the Driver Amplifier.

The -15 V Regulator output voltage is compared to the voltage of the reference zener CR107 by the differential feedback amplifier comprising Q108, Q109, Q105, Q103, and pass transistor Q2. Feedback is degenerative so that Q2 keeps the -15 V output constant with reference to the voltage on CR107. CR103, CR104, and CR105 require a combined cathode to anode drop of about 2 V to forward bias them. If the Regulator load current, passing through R106, exceeds the value required to forward bias the diodes by developing sufficient voltage across R106, the reduced base-emitter voltage of Q2 tends to turn Q2 off to limit the Regulator load current.

The +15 V Regulator is the same as the -15 V Regulator; the only difference is that the -15 V Regulator output voltage is used to reference the +15 V Regulator.

SECTION V
ALIGNMENT PROCEDURE

5.1 INTRODUCTION

The Model 152 Cryogenic Temperature Controller should not require alignment except possibly if a component is replaced or one of the settings is disturbed. An exception to this is the Power Amplifier voltage gain adjustment which must be adjusted each time the heater is changed. These procedures should be performed in sequence, except for the Power Amplifier voltage gain, which may be adjusted individually when the heater is changed. Refer to the schematic diagrams and component location diagrams in Section VIII when locating test points and adjustments.

5.2 EQUIPMENT NEEDED

(1) Dummy load equal in resistance to the Cryogenic System Heater resistance (about 20 ohms 5 watts).

(2) 100 kilohm resistor.

(3) Precision high impedance dc voltmeter, such as a Hewlett Packard Model 419A.

(4) Soldering iron (no larger than 40 watts).

5.3 PROCEDURE

(1) Power Supply

(a) Monitor the -15 V bus, and adjust R120 for -15 V ±10 mV.

(b) Monitor the +15 V bus, and adjust R113 for +15 V ±10 mV.

(2) Integrator Offset Adjust

(a) Turn the Gain and Differentiator controls fully counterclockwise, and turn the Integrator control clockwise one-half turn. (Heater switch to Manual.) This grounds the input to A100, disables the Differentiator, and leaves the Integrator functional.

(b) Monitor the A100 output from pin 32 (junction of R160 and the Integrator potentiometer). The maximum output will be approximately ±9.5 V. Reduce this voltage below 2 V by short-circuiting C115 with a clip-lead. If an offset is present, the voltage will build in either the + or the - direction. Adjust R150 to achieve minimum build-up or drift. The drift rate should be less than 20 mV/min.

(3) Power Am

(a) With

(a) Connect the 20 ohm dummy load to the smaller pair of rear panel terminals.

(b) With the Manual Heater control fully clockwise, adjust R171 for 500 mA on the Heater Current meter.

adjust R171 for 500 mA on the Heater Current meter with the Manual control fully clockwise.

(4) Diode Reference Adjustments

(a) Connect the 100 kilohm resistor across the larger pair of rear-panel terminals in place of the diode.

(b) Use the soldering iron to lift the R209-side of R212 (jumper provided; see Differential Amplifier layout diagram), and use a clip-lead to connect this side of R212 to terminal 45 on the board (wiper arm of set-point potentiometer).

(c) Adjust R213 for a null on the front-panel Null meter.

(d) Monitor the voltage across the 100 kilohm resistor installed in place of the diode. Adjust R207 for 1 V ±10 mV across this resistor. (Range switch to High.) This voltage must be measured with a high-impedance voltmeter (> 10 megohms).

(e) Monitor the voltage across R206, and adjust R200 for 0.3 V ±5 mV.

(f) Monitor the voltage across R7 (10-turn Set-Point potentiometer on the front panel), and adjust R204 for 1 V ±10 mV.

(g) Replace the R212-lead jumper.

(h) Note that the Nullmeter zeros at approximately half-range (x five turns from zero) on the Set Point potentiometer.

SECTION VI
TROUBLESHOOTING

6.1 INTRODUCTI(

The Model 152 Cryogenic Temperature Controller is a stable, reliable instrument, and should provide long trouble-free service. Occasionally, component failure may occur, and troubleshooting may be necessary. The procedure outlined in the next paragraph will be helpful. Once the problem is isolated to a specific circuit or component (or before), the user should contact Princeton Applied Research Corporation for advice on the relative merits of repairing the instrument himself, as opposed to returning it to the factory for repair. In any case, if the instrument is still in WARRANTY (Section VII), it is particularly important that an authorized PAR representative be contacted prior to attempting a field repair, as failure to do so could invalidate the Warranty.

6.2 PROCEDURE

To speed the troubleshooting process, try to determine any external causes of the trouble, and ascertain the symptoms when the Controller is properly connected and tested. The set-up and procedures given in Section II, the Initial Checks, together with the functional description given in Section III (the Operating Instructions), will be helpful in determining the symptoms independently of the Cryogenic system. Section IV, the Circuit Description, together with the layout diagram and schematics (Section VIII), should provide sufficient information for isolating the trouble. A possible approach is to isolate the trouble to the Power Supply, ±15 V Regulators, Differential Amplifier, Computer Circuitry, Bound Circuitry, or Driver Amplifier, by functional and voltage checks. Voltage and resistance checks can then specifically pinpoint the trouble. When doing resistance checks, it is sometimes possible to locate a bad transistor by checking the diode action of the base and collector junctions. While doing voltage checks, it is useful to remember that the base-to-emitter voltage of a forward biased silicon transistor (or diode junction) is roughly 0.6 V, and that the collector voltage of a saturated transistor is less than the base voltage (measured with respect to the emitter). Additionally, the collector current of a forward biased unsaturated transistor is beta times the base current, with typical betas ranging from 100 to 400.

When troubleshooting and replacement of bad components are completed, it will probably be necessary to adjust some of the bias and dc offset trimpots. Section V, the Alignment Procedures, should be consulted.

6.3 PRINTED CIRCUIT SOLDERING

If any components are removed from a printed-circuit board for inspection or replacement, be especially careful not to damage the print. To remove components "cleanly" requires considerable care. Either one of two methods can be used to remove the solder from a pad. The first entails the use of a bulb-vacuum operated solder remover, and the second the use of a "wick". Both methods give good results. A brief description of each follows.

METHOD #1

Removing solder by means of a solder-remover is a straightforward and relatively simple process. The required equipment includes a bulb-vacuum operated solder remover (UNGAR type SOLDER-OFF #7805 recommended) and a good soldering iron of moderate power (WALL type 14HDG40120 with type W14KS tip). The specific procedure used depends on whether the component to be removed has bent or straight leads. Most of the components have bent leads. Because of this, the solder must be removed from the pad on the side opposite the component, and each lead must be straightened before the component can be removed. In case the "opposite" side of the board is not accessible, the solder must be removed from the component side. To make their removal easier, the leads of these components were left straight by the instrument manufacturer. To remove a component, proceed as follows:

(1) Bent-Lead Components

Heat the pad on the side opposite the component. As soon as the solder flows, use the solder-remover to remove the solder from the pad and hole. Take care not to prolong the heating any longer than necessary. After the solder has been removed, straighten the lead. If enough solder has been removed so that the lead is "free" in the hole, pull the lead through the hole from the component side of the board, using suitable long-nose pliers. If the lead is not free, continue to apply heat while pulling the lead from the hole. Components with leads which cannot be removed one-at-a-time must have all of the leads free in the holes simultaneously by use of the solder remover. If it is not possible to free all of the leads in the holes, the component can be removed by applying heat to one of the leads and "rocking" the component to pull the lead through the hole as far as possible, and successively repeating this for each of the unfree leads until the component is free from the board. After the component has been removed, use the solder remover to completely clear all solder from the holes.

(2) Straight-Lead Components

Heat the lead on the same side as the component. As soon as solder flows, pull the lead through the hole. The above "rocking" procedure may be necessary. When the component has been removed, use the solder remover to completely clear all solder from the holes.

METHOD #2

Wicking entails using a length of stranded wire or shielding braid as a wick to draw up the molten solder from the pad. With this method, exceptionally clean work is easily achieved. Equipment required includes a good soldering iron (that recommended in Method #1 above is excellent), a supply of stranded wire or shielding braid, and some rosin base soldering flux (ALPHA 346-35, or equivalent). As in the first method, the technique varies according to whether the component has bent or straight leads:

(1) Bent-Lead Components

Dip a few inches of stranded wire (shielding braid is ideal) into the rosin-base soldering flux. Then place the wire or braid on top of the joint to be unsoldered, allowing some of the flux to flow over the joint. NOTE: Under no circumstances use an acid-base flux.

As shown in Figure VI-1, place a hot soldering iron on top of the stranded wire directly above the joint to be unsoldered. Within a few seconds, most of the solder in the joint will flow quickly up the wick, leaving the joint area free of solder.

Lift the soldering iron and remove the wick before it freezes to the joint. Cut off the "filled" end of the wick (generally about ½ inch should be removed).

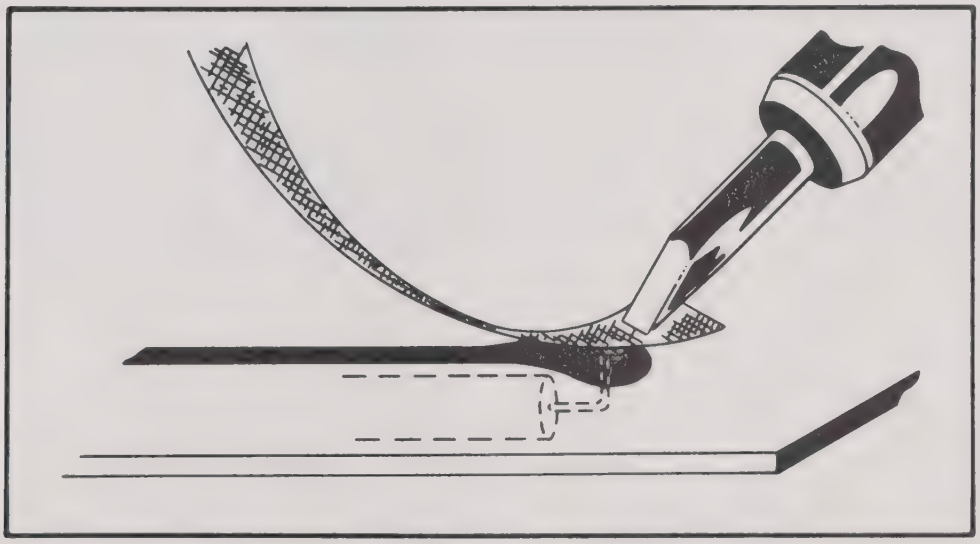


Figure VI-1. SOLDER REMOVAL BY WICKING

Inspect the joint. If any solder remains, repeat the procedure as required. Then straighten the lead and, while applying heat to keep the solder in the hole molten, pull it through the hole. Components with leads which cannot be removed one-at-a-time, such as transistors and trim-potentiometers, can be removed by applying heat to one of the leads and "rocking" the component to pull the lead through the hole as far as possible, and successively repeating this for each of the leads until the component is free from the board. After the component has been removed, use wicking to completely clear all solder from the holes.

(2) Straight-Lead Components

Heat the lead on the same side as the component. As soon as solder flows, pull the lead through the hole. The above "rocking" procedure may be necessary. When the component has been removed, use wicking to completely clear all solder from the holes.

INSTALLING COMPONENTS

In returning the component or its replacement to the board, make sure the leads are bent on the proper centers and that they don't angle in or out. If they do not pass freely through the centers of the holes, they may catch the edge of the print and lift it. The leads of straight-lead components must be cut before installing the component. In case of bent-lead components, bend and cut the leads after inserting the component. In either case, solder the leads with a hot iron (no larger than 40 watts) and a good grade of rosin core 60/40 solder. Be sure to apply heat no longer than necessary to achieve a good joint (usually a few seconds). Straight-lead components are, of course, soldered from the component side of the board. Bent-lead components are soldered from the opposite side.

SECTION VII
WARRANTY

Princeton Applied Research Corporation warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this Warranty are limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned prepaid to our factory for that purpose within ONE year of delivery to original purchaser. Instruments returned to the factory are accepted only when prior authorization has been given by an authorized representative of Princeton Applied Research Corporation.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control.

Princeton Applied Research Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This Warranty is in lieu of, and excludes all other warranties or representations, expressed, implied or statutory, and all other obligations or liabilities of Princeton Applied Research Corporation including special or consequential damages, and no other source is authorized to assume for Princeton Applied Research Corporation any other liability.

SECTION VIII
SCHEMATICS

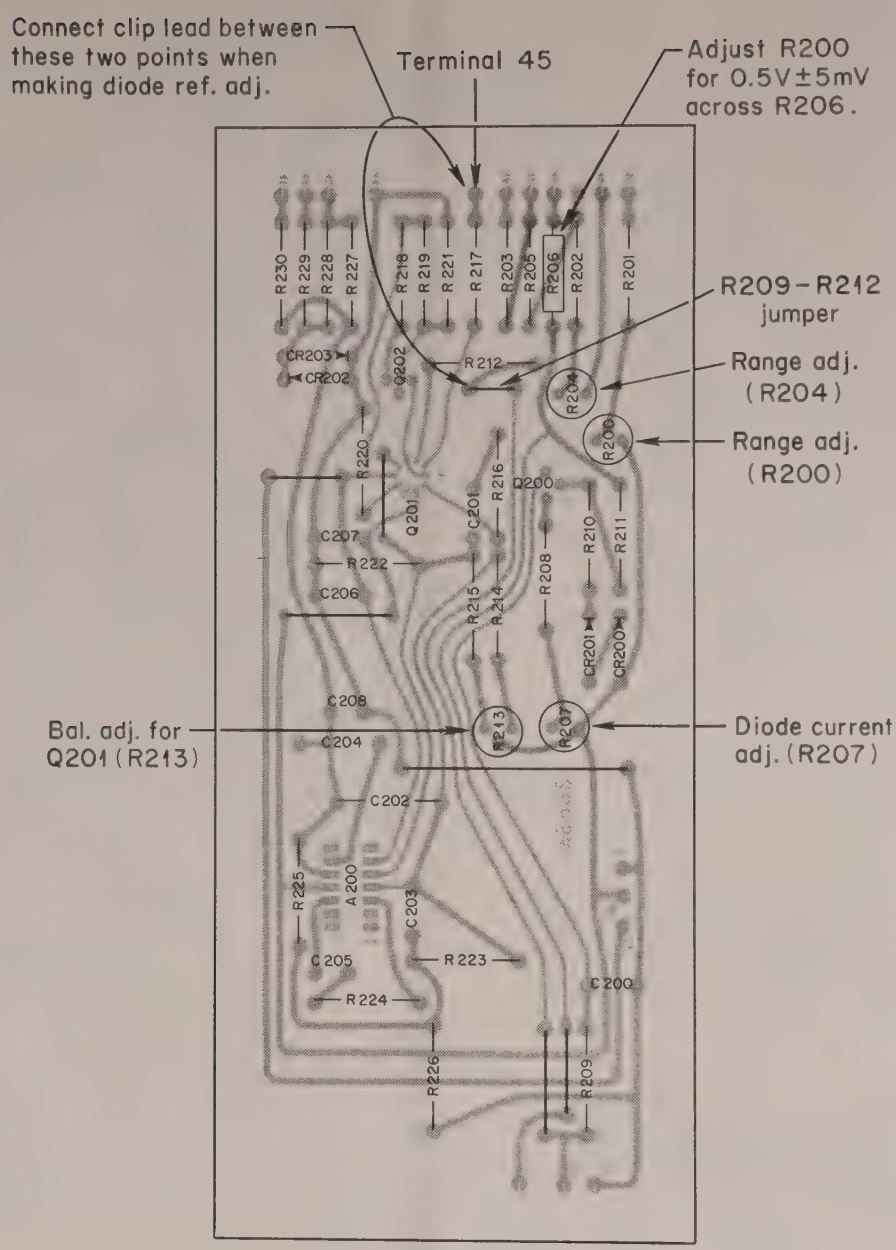
Page

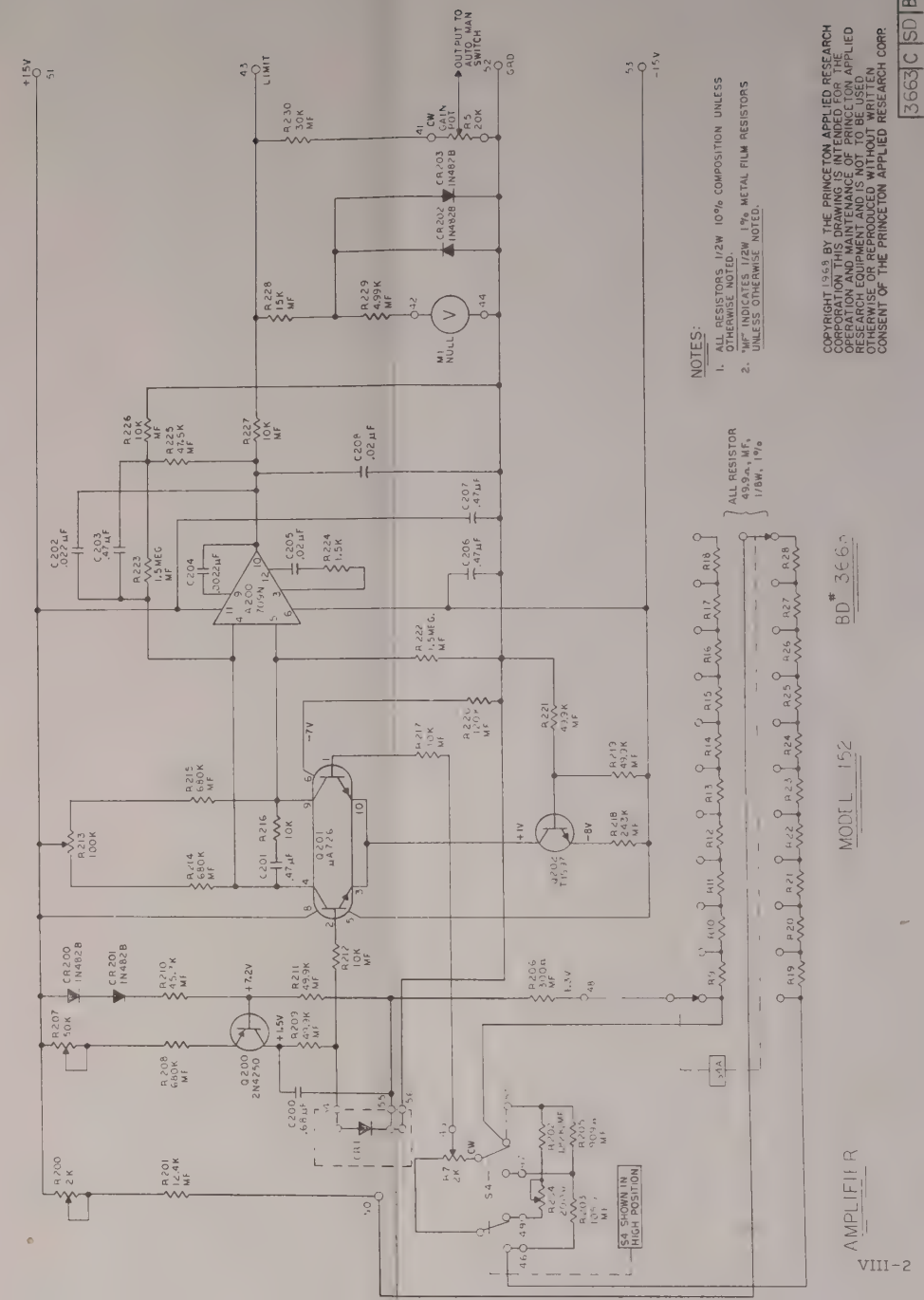
TABLE OF SCHEMATICS ---------- VIII-1

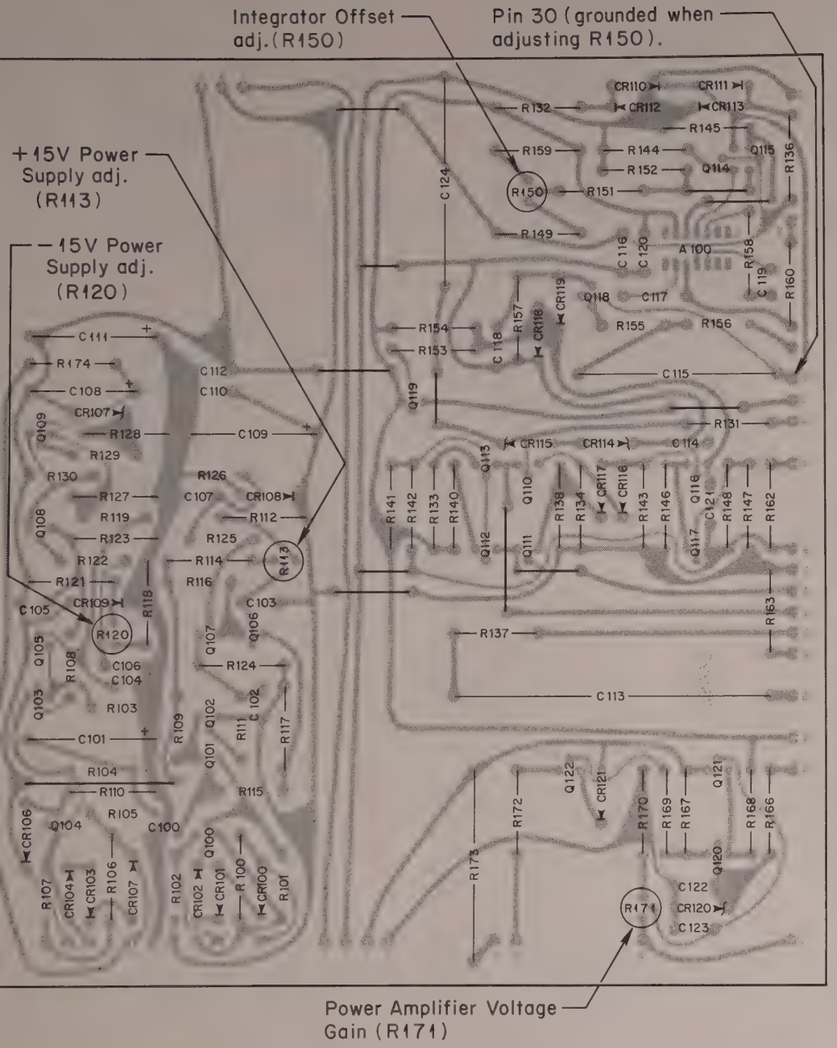
DIFFERENTIAL AMPLIFIER ---------- VIII-2

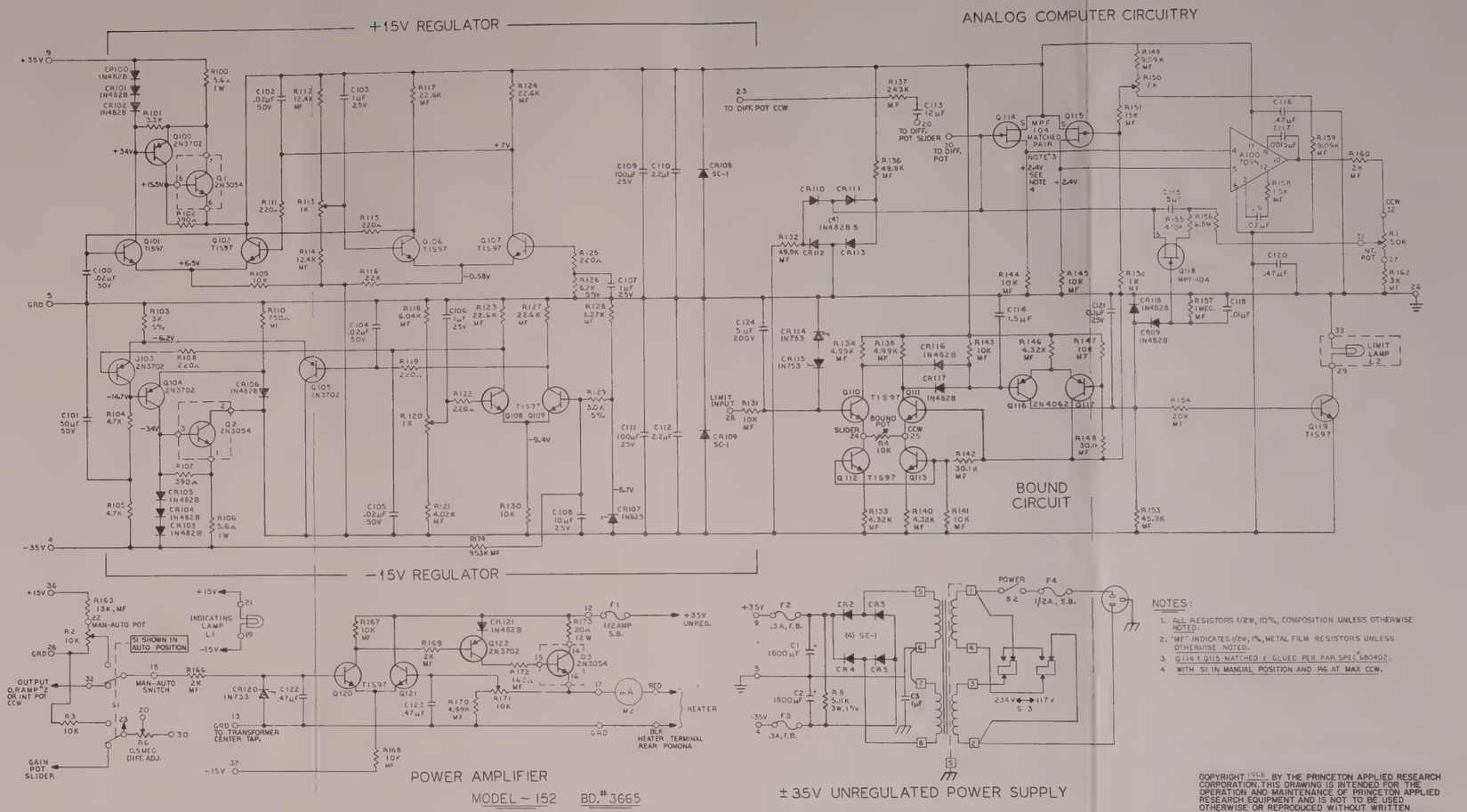
COMPUTER, BOUND CIRCUITRY, DRIVER
AMPLIFIER, AND POWER SUPPLY ---------- VIII-3

TYPICAL SENSOR DATA SHEET ---------- VIII-4


Connect clip lead between these two points when making diode ref. adj.
Terminal 45
Adjust R200 for 0.5V±5mV across R206.
R209-R212 jumper
Range adj. (R204)
Range adj. (R200)
Bal. adj. for Q201 (R213)
Diode current adj. (R207)
R230
R229
R228
R227
R218
R219
R221
R217
R203
R205
R206
R202
R201
CR203
CR202
Q202
R212
R204
R200
R220
Q201
C201
R216
Q200
C207
R222
C206
R215
R214
R208
R210
R211
CR201
CR200
C208
R213
R207
C204
C202
R225
A200
C203
C205
R223
C200
R224
R226
R209


+15V
51
LIMIT
OUTPUT TO AUTO MAN SWITCH
GAIN
GND
-15V
R230 30K MF
R228 15K MF
R229 4.99K MF
M1 NULL
R226 10K MF
R227 10K MF
R225 47.5K MF
C208 .02µF
C207 .47µF
C202 .022µF
C203 .47µF
R223 1.5MEG MF
C204 .0022µF
A200 741N
C205 .02µF
R224 1.5K
C206 .47µF
R222 1.5MEG MF
R215 680K MF
R213 100K
R214 680K MF
C201 .47µF
R216 10K
Q201 µA726
R217 10K MF
R220 1.5MEG MF
R221 49.9K MF
R219 49.9K MF
Q202 TIS97
R218 24.3K MF
CR200 IN4828
CR201 IN4828
R210 15.4K MF
+7.2V
R211 49.9K MF
R207 50K
R208 680K MF
Q200 2N4250
R203 49.9K MF
+1.5V
C200 .68µF
R206 100K MF
1.3V
R200 2K
R201 12.4K MF
S4 SHOWN IN HIGH POSITION
NOTES:
1. ALL RESISTORS 1/2W 10% COMPOSITION UNLESS OTHERWISE NOTED.
2. "MF" INDICATES 1/2W 1% METAL FILM RESISTORS UNLESS OTHERWISE NOTED.
ALL RESISTOR 49.9Ω, MF, 1/8W, 1%
COPYRIGHT 1968 BY THE PRINCETON APPLIED RESEARCH CORPORATION THIS DRAWING IS INTENDED FOR THE OPERATION AND MAINTENANCE OF PRINCETON APPLIED RESEARCH EQUIPMENT AND MAY NOT BE USED FOR ANY OTHER PURPOSE NOR LOANED WITHOUT WRITTEN CONSENT OF THE PRINCETON APPLIED RESEARCH CORP.
3663 C SD B
BD# 3660
MODEL 152
AMPLIFIER


Integrator Offset adj.(R150)
Pin 30 (grounded when adjusting R150).
+15V Power Supply adj. (R113)
−15V Power Supply adj. (R120)
Power Amplifier Voltage Gain (R171)


+15V REGULATOR
ANALOG COMPUTER CIRCUITRY
BOUND CIRCUIT
−15V REGULATOR
POWER AMPLIFIER
MODEL − 152 BD.# 3665
±35V UNREGULATED POWER SUPPLY
NOTES:
1. ALL RESISTORS 1/2W, 10%, COMPOSITION UNLESS OTHERWISE NOTED.
2. "MF" INDICATES 1/2W, 1%, METAL FILM RESISTORS UNLESS OTHERWISE NOTED.
3. Q114 & Q115 MATCHED & GLUED PER PAR SPEC 680402.
4. WITH S1 IN MANUAL POSITION AND R6 AT MAX CCW.

COPYRIGHT 1968 BY THE PRINCETON APPLIED RESEARCH CORPORATION. THIS DRAWING IS INTENDED FOR THE OPERATION AND MAINTENANCE OF PRINCETON APPLIED RESEARCH EQUIPMENT AND IS NOT TO BE USED OTHERWISE OR REPRODUCED WITHOUT WRITTEN CONSENT OF THE PRINCETON APPLIED RESEARCH CORP.

TG-100 CRYO-SENSOR

SOLID STATE THERMOMETER

USEFUL RANGE – BELOW 1°K TO 400°K

TG-100 thermometers are manufactured with advanced state of the art techniques to assure surface and contact introduced errors do not exist. These techniques assure that the useful range from 1°K to 400°K will not be degraded with time.

THERMOMETER SPECIFICATIONS

ACCURACY: Guaranteed to sense temperature changes equal to 5 microvolts (5 parts in 10^6) at 100 microamps current when utilized with suitable readout equipment.

SENSITIVITY: −1.8 mv/°K from 77°K to 300°K and 100 ua.,
−1.1 mv/°K at 20°K and 100 ua., and
−0.7 mv/°K at 4.2°K and 100 ua.

MATERIAL: Gallium Arsenide diode

WEIGHT: 0.2 grams nominal

IMPEDANCE: 7000 to 15000 ohms at 100 uamps nominal

PACKAGE: Model TG-100K is a Gold-plated Kovar TO-46 header package assuring good thermal conductivity between thermometer and medium to be measured.

Model TG-100P is an all platinum and glass package for use where magnetic materials are undesirable.

Figure 1 gives dimensions of above packages. Special packages quoted on request.

LONG TERM STABILITY: No degradation measurable.

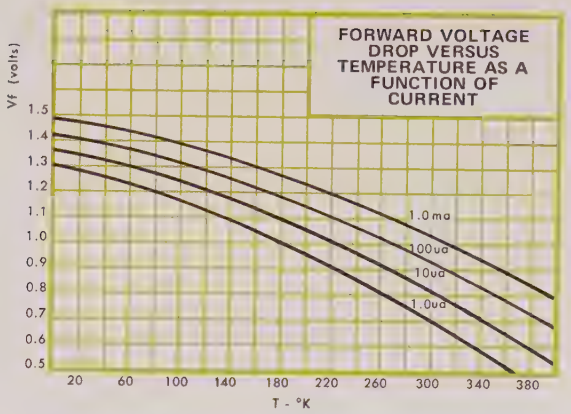
SELF HEATING: Less than .001°K over useful range at recommended current of 100 ua.

MAGNETIC FIELDS EFFECT: All semi-conductors exhibit a Hall effect. Typical effect of a magnetic field on the TG-100 is:

less than −.2°K at 10 Kilo Gauss
less than −.5°K at 20 Kilo Gauss
Typical data for higher fields available on request.

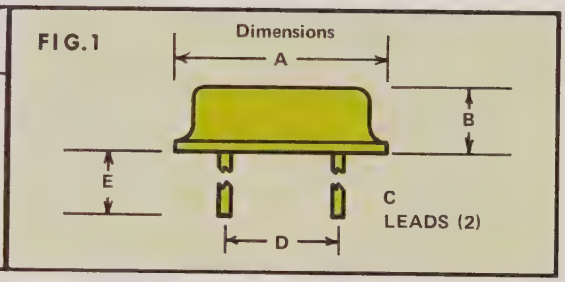
METHOD OF ATTACHMENT: The TG-100 thermometers may be bonded to any surface with any high conductivity material so long as the temperature does not exceed 150°C. Proper electrical isolation between leads is important. Calibrated sensors should have their leads soldered to tempering leads with accessory heat sink clips between the header and solder points.

The TG-100 thermometer is useful in any application across the range of 1.0°K to 400°K. These thermometers should have their outputs measured by a Mueller bridge if extreme accuracy is required. Less elaborate equipment will allow accuracy of ±¼°K. With a higher sensitivity than available before from such thermometers as platinum, etc., greater low temperature accuracy, coupled with rugged reliability, is now available.



SENSITIVITY vs. FORWARD CURRENT FOR A GaAs TEMP. SENSOR

	230" 075" 019"D .100" .500 Min.	.150" .065" .010"D .060" .500 Min.



APPLICATION METHODS of TG-100 for TEMPERATURE MEASUREMENT

Recommended two-lead system where accuracy requirement does not require lead compensation. Recommended current for optimum usage is 100u a, or less.

Recommended four-lead system for use when optimum accuracy is desired and lead compensation is required. Recommended current for optimum usage is 100u a, or less.

The current regulation required to obtain a specified accuracy in temperature measurements increases at higher temperatures, however, the voltage resolution required to obtain the same accuracy increases at lower temperatures. Worst case values for current regulation and voltage resolution are given at right for specified accuracies.

Temp. Accuracy	Constant Current Supply % Regulation	Voltmeter Accuracy	Voltmeter Resolution
1°	5%	.06%	Resolve 600uV in 1 volt
.1°	.5%	.006%	Resolve 60uV in 1 volt
.01°	.05%	.0006%	Resolve 6uV in 1 volt
.001°	.005%	.00006%	Resolve 0.6uV in 1 volt

LAKE SHORE CRYOTRONICS, INC.
P. O. BOX 214
HAMBURG, N. Y. 14075

LB-681
PRINTED IN U.S.A.

SALES OFFICES

PRINCETON APPLIED RESEARCH

DOMESTIC SALES OFFICES AND REPRESENTATIVES

(INTERNATIONAL OFFICES LISTED ON REVERSE SIDE)

MAIN OFFICE
PRINCETON APPLIED
RESEARCH CORP.
P.O. Box 565
Princeton, New Jersey 08540
Phone: (609) 924-6835
TELEX: 84-3409

SHIPPING ADDRESS
PRINCETON APPLIED
RESEARCH CORP.
Rte. 518 E. of Rte. 206
Princeton, New Jersey

1. PRINCETON APPLIED
RESEARCH CORP.
17 Dunster Street
Cambridge, Mass. 02138
Phone: (617) 491-6800

2. PRINCETON APPLIED
RESEARCH CORP.
4922 St. Elmo Avenue
Bethesda, Md. 20014
Phone: (301) 652-0010

3. TECHNICAL ASSOCIATES, INC.
2319 East South Street
Orlando, Fla. 32803
Phone: (305) 424-5681

P.O. Box 4088
Huntsville, Ala. 35802
Phone: (205) 881-8494

P.O. Box 5583
Spartanburg, S.C. 29301
Phone: (803) 585-3864

4. WKM ASSOCIATES
16141 Puritas Rd.
Cleveland, Ohio 44135
Phone (216) 267-0445

5335 Far Hills Avenue
Dayton, Ohio 45429
Phone: (513) 434-7500
TWX: 810-459-1687

1474 East Outer Drive
Detroit, Mich. 48234
Phone: (313) 892-2500
TWX: 810-243-4110

90 Clairton Blvd.
Pittsburgh, Penna. 15236
Phone: (412) 892-2953
TWX: 710-667-4858

5. BARD ASSOCIATES, INC.
LaGrange Industrial Park
LaGrange, Ill. 60525
Phone: (312) 354-0660
TWX: 910-683-1894

4000 Meadows Drive
Indianapolis, Ind. 46205
Phone: (317) 547-3113

4640 West 77th Street
Minneapolis, Minn. 55435
Phone: (612) 922-8233

6. POLY-ONICS, INC.
4434 West 90th Terrace
Leawood, Kansas 66207
Phone: (913) 648-4173
TWX: 910-749-6479

47 Village Square Shopping Center
Hazelwood, Mo. 63042
Phone: (314) 837-0597
TWX: 910-760-1708

7. NOAKES ENGINEERING
P.O. Box 968
Irving, Texas 75060
Phone: (214) 255-0441
TWX: 910-860-5903

Suite A-120
6001 Gulf Freeway
Houston, Texas 77023
Phone: (713) 923-1634

8. PRINCETON APPLIED
RESEARCH CORP.
P.O. Box 565
Princeton, N.J. 08540
Phone: (609) 924-6835
TELEX: 84-3409

9. F. Y. GATES COMPANY, INC.
455 East Fourth South
Salt Lake City, Utah 84111
Phone: (801) 359-1101

2631 Texas, N.E.
Albuquerque, N.M. 87110
Phone: (505) 298-1875

1930 South Navajo
Denver, Colo. 80223
Phone: (303) 761-0591

10. AVIONICS LIAISON, INC.
6770 Perimeter Road South
Seattle, Wash. 98108
Phone: (206) 767-3870
TWX: 910-444-2013

11. PRINCETON APPLIED
RESEARCH CORP.
Suite 118
1299 Bayshore Highway
Burlingame, Calif. 94010
Phone: (415) 347-0786

12. PRINCETON APPLIED
RESEARCH CORP.
Suite D
905 N. Euclid Street
Anaheim, Calif. 92801
Phone: (714) 635-6710

ALASKA, HAWAII
PRINCETON APPLIED
RESEARCH CORP.
P.O. Box 565
Princeton, N.J. 08540
Phone: (609) 924-6835
TELEX: 84-3409

CANADA
RADIONICS LIMITED
195 Graveline Street
Montreal 9, Quebec
Canada
Tel: (514) 735-4565
TWX: 610-422-3070

376 Churchill Avenue
Ottawa 3, Ontario
Canada
Tel: (613) 728-4624

3062 Chemin des Quatre-
Bourgeois
Quebec 10, Quebec
Canada
Tel: (418) 651-5845

505 Eglinton Avenue, West
Toronto 12, Ontario
Canada
Tel: (416) 483-7191

2182 West 12th Avenue
Vancouver 9, B.C.
Canada
Tel: (604) 732-7317
TWX: 610-929-1082

INTERNATIONAL DISTRIBUTORS

ARGENTINA
COASIN S.A.
Virrey Del Pino 4071
Buenos Aires, Argentina
Tel: 52-3185 Cable: COASIN
51-9363 Telex: 012-2284

AUSTRALIA
PYE INDUSTRIES LTD.
TECHNICO ELECTRONICS DIV.
P.O. Box 12
53 Carrington Road
Marrickville, N.S.W. 2204
Australia
Tel: 55-0411
Telex: SYDNEY 21490
Cable: PYIND SYDNEY

P.O. Box 222
2-18 Normanby Road
South Melbourne, VIC 3205
Australia
Tel: 69-6961
Telex: MELBOURNE 31240
Cable PYIND MELBOURNE

AUSTRIA
INTERNATIONAL ENGINEERING
SERVICES
Postfach 30
A-1133 Vienna, Austria
Tel: 82 46 732

BELGIUM
PRINCETON APPLIED
RESEARCH
(France) S.A.R.L.
53 Avenue Lenine
Gentilly 94, France
Tel: 655-53-53
Cable: PRINCETON-GENTILLY

BRASIL
AMBRIEX S.A.
Av. Graca Aranha, 226-6°
Rio de Janeiro, G B, Brasil
Tel: 42-7990 Cable: RAIOCARDIO

Av. Pacaembu 811
Sao Paulo, S P, Brasil

CZECHOSLOVAKIA
INTERNATIONAL ENGINEERING
SERVICES
Postfach 30
A-1133 Vienna, Austria
Tel: 82 46 732

DENMARK
PARATRON A/S
Fredericiagade 16
1310 Copenhagen K
Phone (01) 115502

EAST GERMANY
ORTEC GMBH
8000 Munchen 13
Frankfurter Ring 81
West Germany
Tel: 0811-359-1001
Telex: 841-528476

FINLAND
HAVULINNA OY
Vuorikatu 16
P.O. Box 10468
Helsinki, 10, Finland
Tel: 61451 Cable: HAVULA
Telex: 12-426

FRANCE
PRINCETON APPLIED
RESEARCH
(France) S.A.R.L.
53 Avenue Lenine
Gentilly 94, France
Tel: 655-53-53
Cable: PRINCETON-GENTILLY

HUNGARY
INTERNATIONAL ENGINEERING
SERVICES
Postfach 30
A-1133 Vienna, Austria
Tel: 82 46 732

INDIA
BALI INTERNATIONAL AGENCIES
P.O. Box 1676
Bombay 1, BR, India
Tel: 264592 Cable: NUCLEONICS

ISRAEL
RACOM ELECTRONICS CO., LTD.
P.O. Box 6170
60 Pinkas Street
Tel Aviv, Israel
Tel: 443126 Cable: RACOM
443127

ITALY
ORTEC ITALIA S.R.L.
via Monte Suelo 19
I-20133 Milan, Italy
Tel: 738-6294

JAPAN
RIKEI TRADING CO., LTD.
Kozato Kaikan Building
18-14 Nishi Shimbashi
1-Chome, Minato-Ku
Tokyo, 105, Japan
Tel: (591) 5246 Cable: RIKEIGOOD
Telex: TK 4 208

NETHERLANDS
NENIMIJ N. V.
P.O. Box 925
16 Nassau Dillenburgstraat
The Hague, Holland
Tel: (070) 24 44 96 Cable: NENIMIJ
Telex: 31706

NEW ZEALAND
AUCKLAND NUCLEAR
ACCESSORY CO., LTD.
12 Wagener Place
Auckland 3, New Zealand
P.O. Box 16066
Tel: 81985 Cable: ADVANCED

NORWAY
HUGO RISO A.S.
P.O. Box 8
Oslo 8, Norway
Tel: 23 2580 Cable: HUGOTEST

POLAND
ORTEC GMBH
8000 Munchen 13
Frankfurther Ring 81
West Germany
Tel: 0811-359-1001
Telex: 841-528476

SWEDEN
TELEINSTRUMENT A.B.
Box 14
Stockholm-Vallingby
Sweden
Tel: 87 03 45
Cable: TELEINSTRUMENT STOCKHOLM

SWITZERLAND
RESISTRONIC AG
Hugistrasse 3
2500 Biel, Switzerland
Tel: 032 356 66 Telex: 34333
Cable: RESISTRONIC

TAIWAN
INDUSTRIAL ELECTRONICS, LTD.
P.O. Box 22423
Taipei, Taiwan
China
Tel: 774257 Cable: LEOTRONIKS

UNION OF SOUTH AFRICA
THOMPSON ELECTRONICS S.A.
(PTY) LTD.
P.O. Box 123
Newville
Transvaal, South Africa
Tel: 27-4321 Cable: RELIHUSA

U.S.S.R.
ORTEC GMBH
8000 Munchen 13
Frankfurter Ring 81
West Germany
Tel: 0811-359-1001
Telex: 841-528476

UNITED KINGDOM
NUCLEAR MEASUREMENTS
Dalroad Industrial Estate
Dallow Road
Luton, Bedfordshire
England
Tel: Luton 27557
Telex: 82477

VENEZUELA
COASIN C.A.
Apartado 50939
Sabana Grande No. 1
Caracas, Venezuela
Tel: 72-9637 Cable: INSTRUVEN

WEST GERMANY
ORTEC GMBH
8000 Munchen 13
Frankfurter Ring 81
West Germany
Tel: 0811-359-1001
Telex: 841-528476

6000 Frankfurt/Main 70
Stresemannallee 61
West Germany
Tel: 62-60-16 Telex: 841-411243

PRINCETON APPLIED RESEARCH CORPORATION

POST OFFICE BOX 565
PRINCETON, N.J. 08540
TELEPHONE 609-924-6835
CABLE: PARCO

F-43-B-10M-5/69-DW

Printed in U.S.A.

MP MASTER
MA30247